ADHERING TO UTILITY INTERCONNECTION STANDARDS MAY NOT GUARANTEE DG SECURITY

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Introduction

DG Interconnection Standards are created and maintained by power companies to assure protection for the utility. They are written primarily to guarantee protection reliability for the utility, and not necessarily for the security of the DG to remain interconnected.

DG interconnection protection must be secure to allow the DG to operate in parallel with utility distribution systems. It also must reliably disconnect the DG from the utility distribution system for various reasons such as: loss of utility supply to the feeder (anti-islanding), shunt faults on the utility system and abnormal operating conditions (including open-series events). Additionally, the protective system should provide restoration elements.

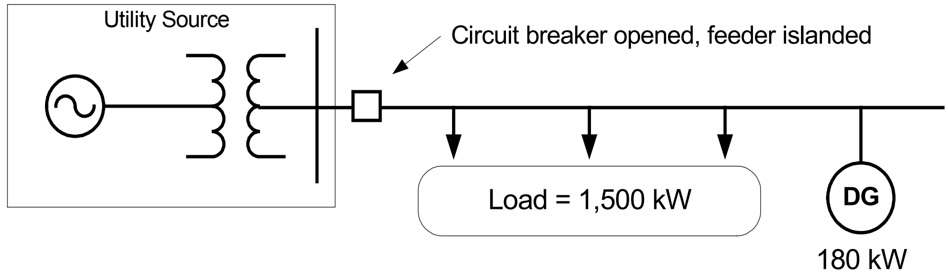
Table 1 Protection Objectives and Elements for DG Interconnection Protection

Protection Objective	Protective Elements
Anti-islanding	Undervoltage (27), Overvoltage (59), Underfrequency (81-U), Overfrequency (81-O), Instantaneous Overvoltage (59I), Directional Power (32F, 32R-U), Rate of Change of Frequency (81R)
Shunt Fault Clearing	Ground Overcurrent (51G), Phase Overcurrent (51V-C/R), Ground Under/Over Voltage (27G/59G)
Abnormal Operating Conditions	Negative Sequence Overvoltage (47), Negative Sequence Overcurrent (46), Loss of Protection Potential (60FL)
Restoration	Reconnection Timer (79), Sync Check (25)

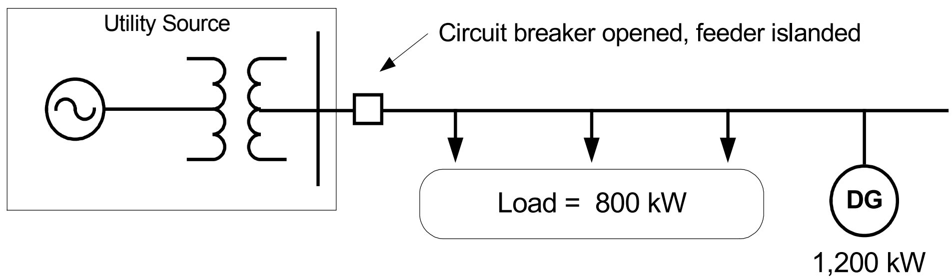
Most protection elements are applied to trip the DG off the distribution system in less than one second, and often much faster (10-30 cycles). These tripping times are mandated in DG interconnection standards, and are generally not open to change. Events can occur on the system and within the DG facility, however, that may lead to undesirable tripping. These trips may occur due to certain protection elements being set with a coordination margin that is too small combined with faults within a DG facility that should be cleared by protection within the facility, and interplay of events that include power surges into the utility from cycling loads within a DG facility. This paper explores these scenarios for unwanted tripping of the DG facility. Specific setting examples are not provided, as they are beyond the scope of this paper, but general concepts and possible solutions are discussed to mitigate undesirable tripping.

Scenario 1: Power Surges from Cycling Loads in the DG Facility

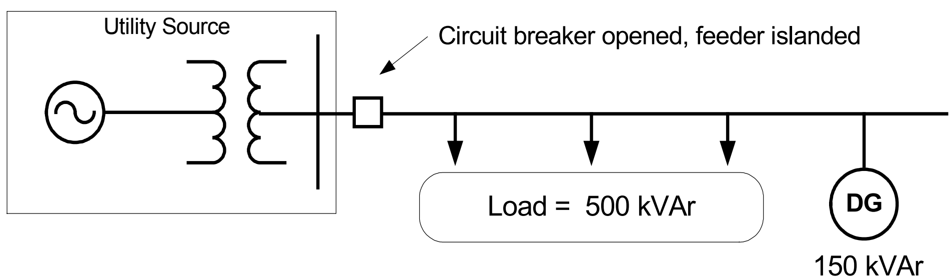
The use of low import power (32R-U) is an additional method of anti-islanding protection, supplementing the typical protections applied when the feeder load does not equal generation such as: underfrequency (81-U), overfrequency (81-O), undervoltage (27), and overvoltage (59) (Figure 1). Instantaneous overvoltage (59I) may also be useful to detect ferroresonance that may result due to self-excitation of induction machines from capacitor banks that can occur after utility disconnection.



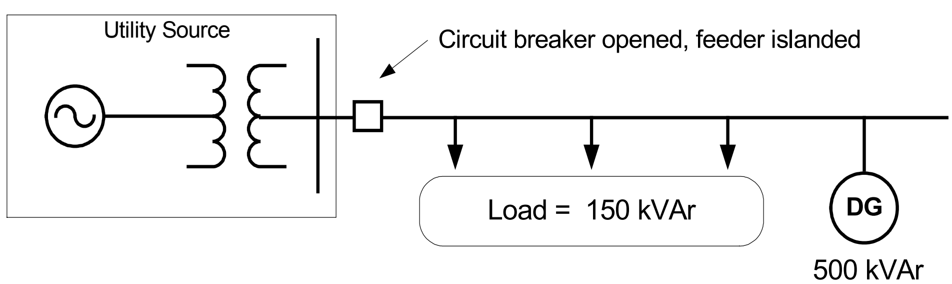
- Load draws too much real power
- Manifests as Underfrequency (81-U)



- Load draws too little real power
- Manifests as Overfrequency (81-O)



- Load draws too much reactive power
- Manifests as Undervoltage (27)



- Load draws too little reactive power
- Manifests as Overvoltage (59)

Figure 1 Typical Islanded Scenario when load does not equal generation

In most cases, the typical protection applied when the load does not equal generation can determine if the utility has disconnected the distribution feeder. But in the unlikely occurrence of the islanded DG(s) on the feeder exactly equaling the feeder load plus losses, an island may be formed (Figure 2).

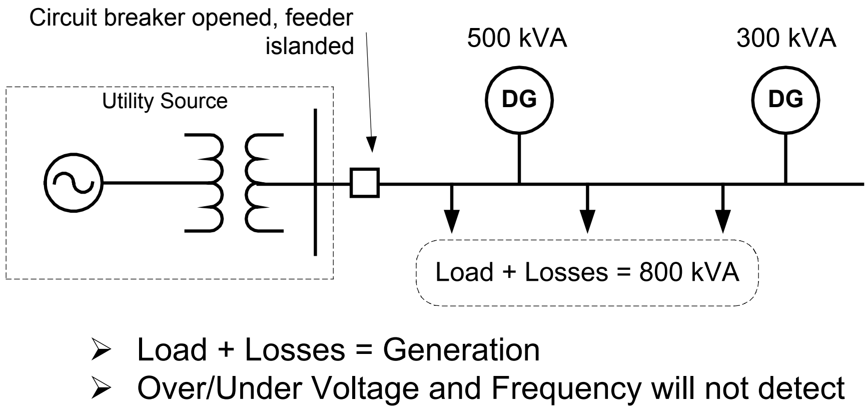


Figure 2 Feeder Islanded, Load + Losses = Generation

A tactic to mitigate this scenario is the use of low import power to assure that the DG facility (or facilities) on a given feeder is importing a small amount of power. This would be the case in peak-shaving applications, and in applications where, by contract, the DG is not allowed to export (Figure 3). A low setting of export power (32F) has also been used for this purpose, but low import power is more reliable. This is because operational situations could occur after utility disconnection from the distribution feeder where the export of even a small amount of power by a few DGs on a given feeder could "hold up" the load plus losses.

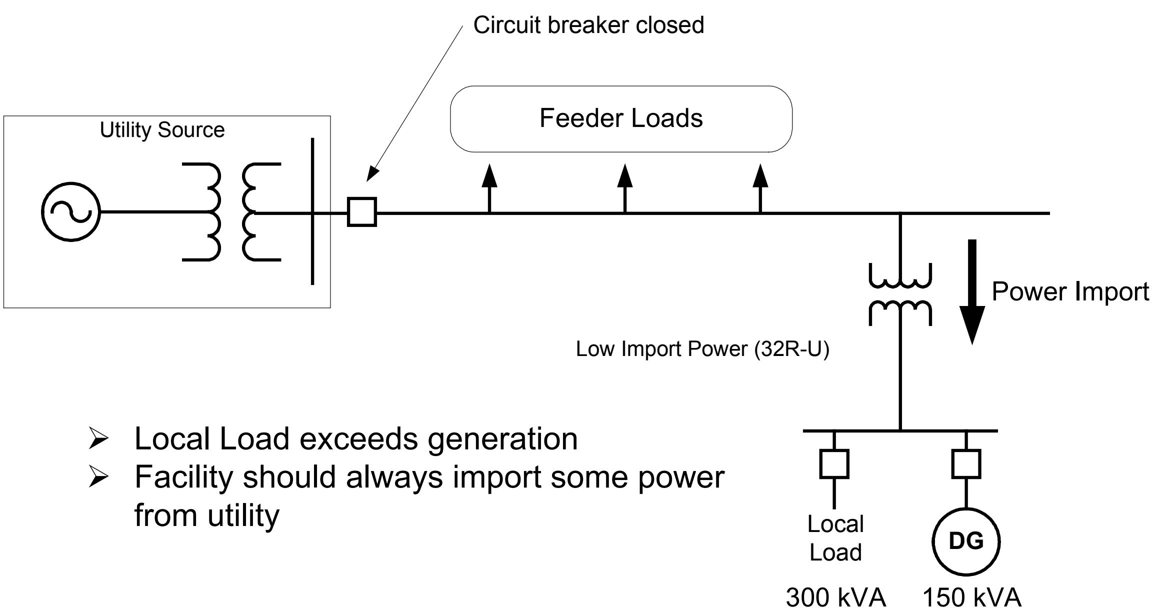


Figure 3 Low Import Power Application

The use of low import power, however, is not without security risks. In a peak-shaving or contractually-imposed, no-power-export situation, it may make economic sense to essentially "float the interchange"—that is, attempt to provide all power used by the DG facility by the on-site DG. This is typically accomplished by precise measurement of facility load, DG supply, and power across the point of common coupling, and control of the DG output (Figure 4).

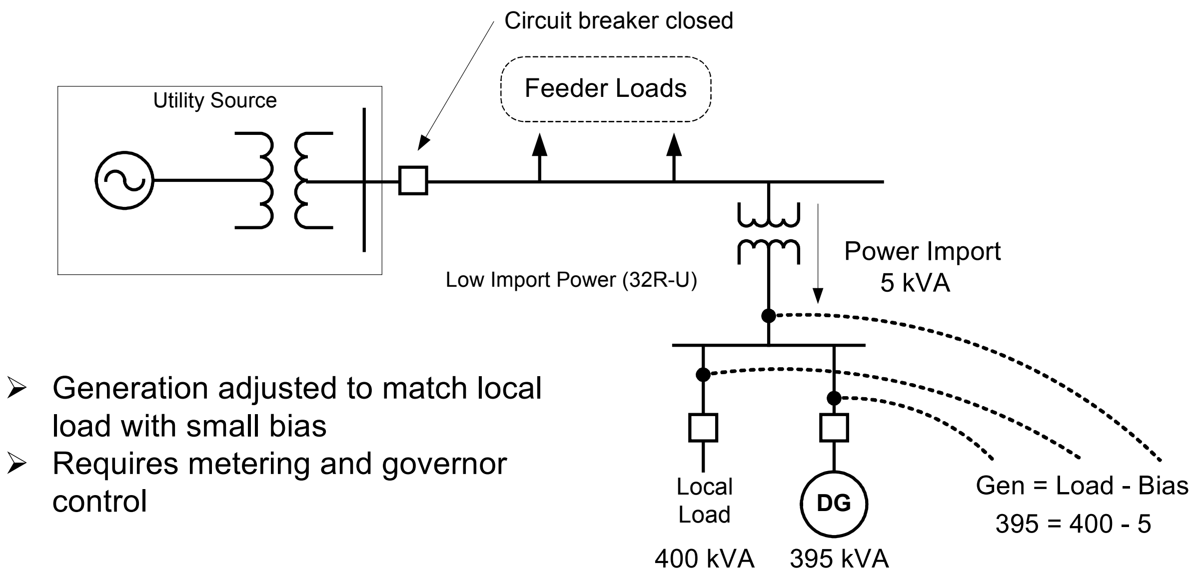


Figure 4 "Floating the Interchange"

In steady-state applications, this "floating" strategy functions well. Caution should be exercised if the DG facility contains a large switched load, such a large block of motors (Figure 5).

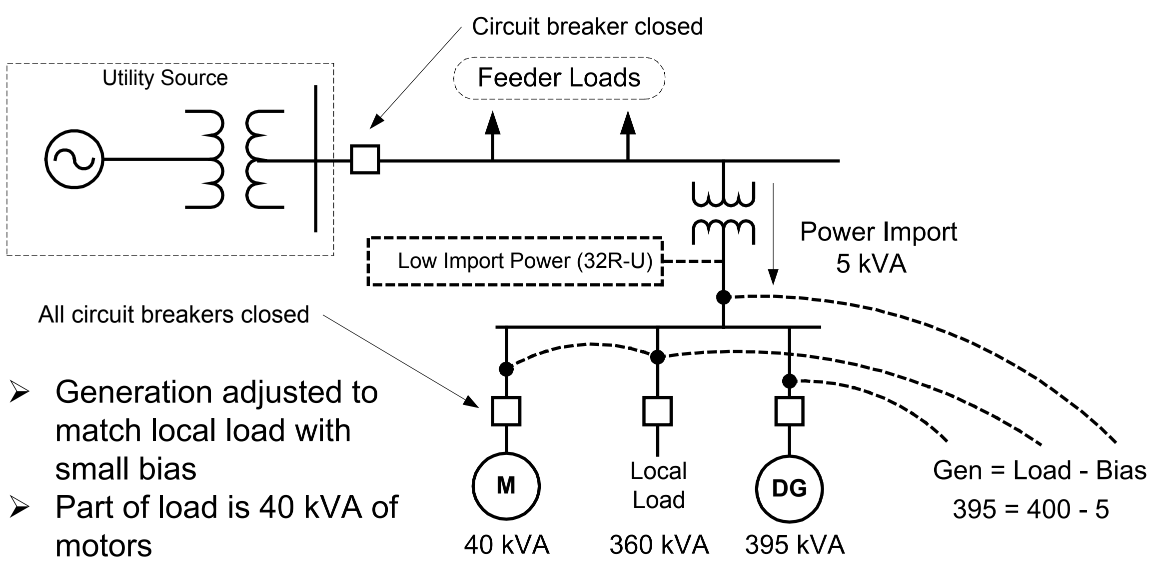


Figure 5 DG Employing Low Import Power Protection with Motor Loads

When these loads are switched off, the rapid change in the load/generation changes, and the change may be too great for the DG's governor system to respond, and a power outflow into the utility may result (Figure 6). If this power outflow lasts longer than the setting of the low import power element (32R-U), a trip will ensue.

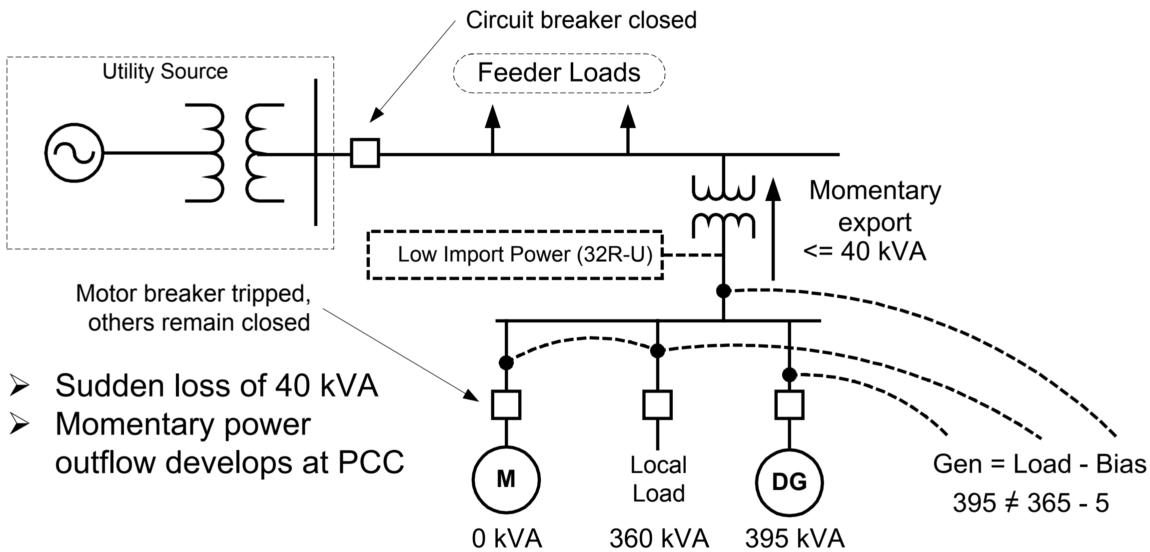


Figure 6 Momentary Power Export After Motors Switched Off

Countermeasures to this possible miscoordination problem are:

1. Increase the bias on the DG governor so that it produces less power, and a wider margin is maintained to account for the load fluctuations (Figure 7). Although the bias can be eventually widened enough so nuisance trips do not occur, it may not be in the economic best interest of the DG facility to import power when the DG is in operation.

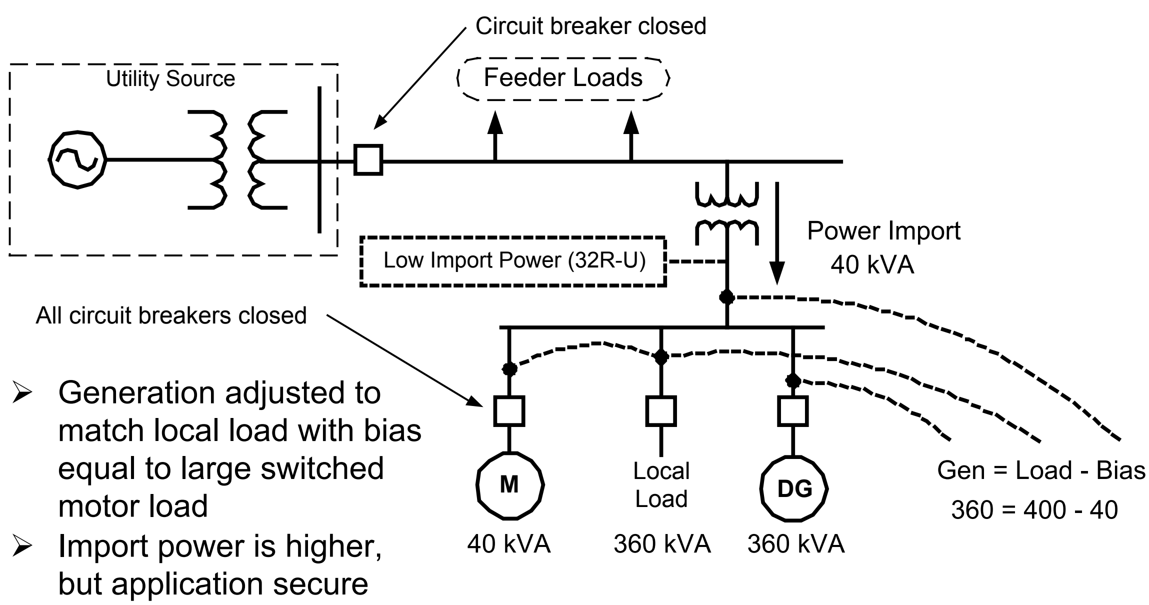


Figure 7 Increasing the Import Bias at the Interconnection for Security

2. Change the operational philosophy of the motor shutdowns within the facility. If a batch process line is to be shut down, then sequentially stop the motors from the feedstock source to the end of the process (Figure 8) if possible. In energy management applications, sequence HVAC and other motor loads in small blocks so that the incremental change occurring at one time is reduced (Figure 9). Additionally, the use of variable speed motor equipment will provide a ramping of the shutdown process that should be within the control capabilities of the DG's governor system.

Another concern of properly applying the low import power element is the ability to block it when the facility disconnects from the utility. At the instant of disconnection, and for the time interval following while it is disconnected, the power import is zero, which violates the low import power element's setting, so it calls for a perpetual trip. The position of the interconnection protection circuit breaker should be used to selectively disable (block) the low import power element when the interconnection breaker is open.

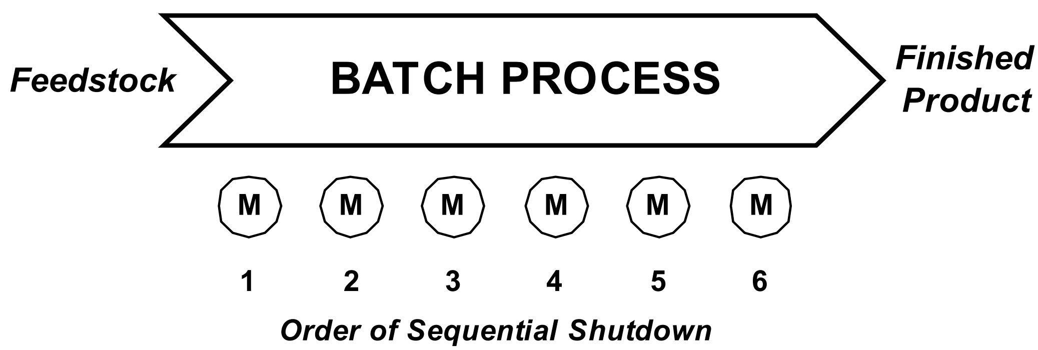


Figure 8 Sequentially Stopping Motors in a Batch Process Operation

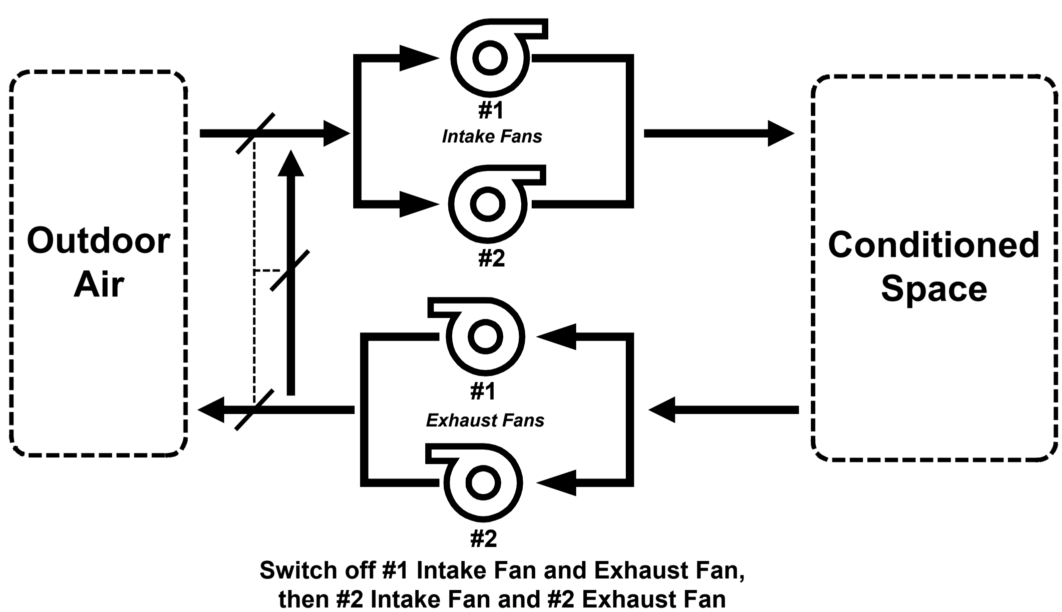


Figure 9 Staged Fan Shutdown in HVAC Systems

Scenario 2: Faults in the DG Facility

Ground overcurrent fault protection (51G), and sometimes phase fault overcurrent protection (51VC or 51VR), may be mandated for DG installation over 100-300 kVA aggregate (Figure 10). Ground overcurrent protection is applied in cases where the interconnection transformer primary (utility side) is a ground source, such as a wye-delta or wye-wye installation. The intention of the protection is to mitigate damage to the utility's infrastructure, including the interconnection transformer, line reclosers and substation breakers and transformers.

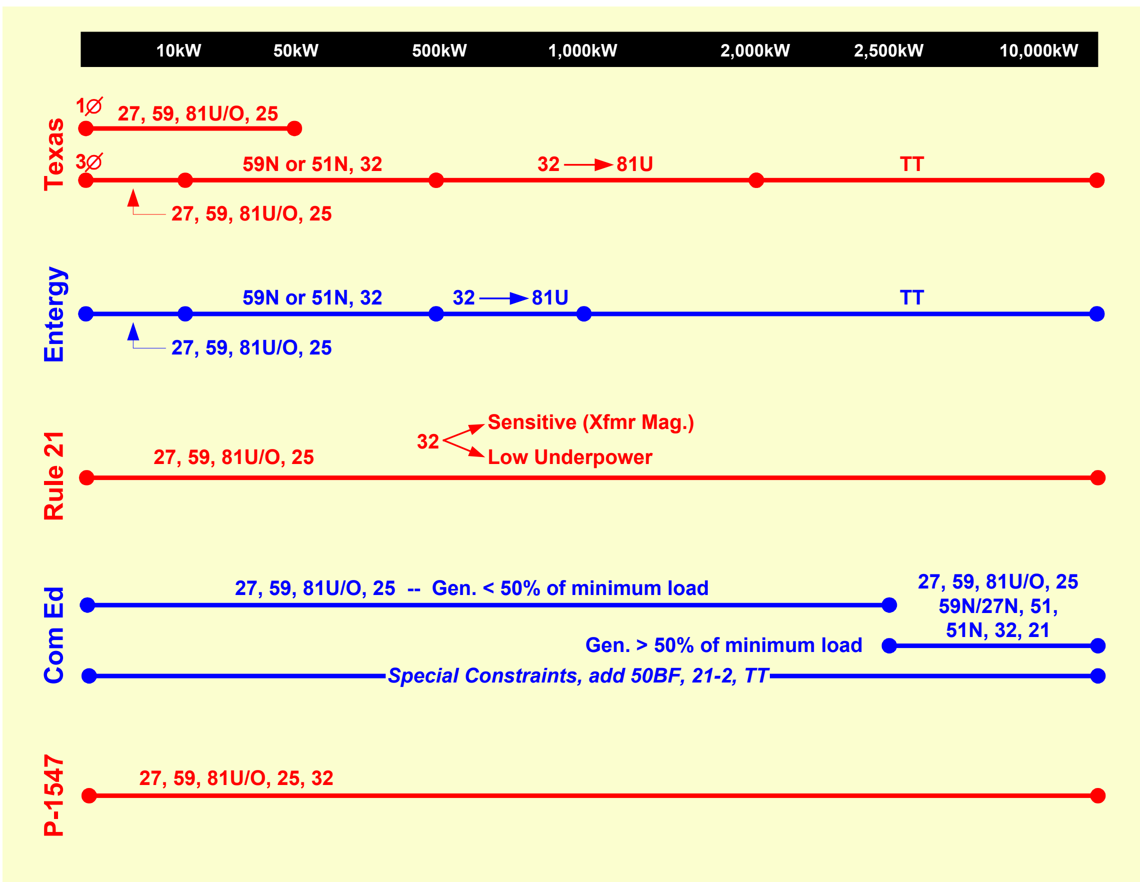


Figure 10 Comparison of Sample Utility Interconnection Guidelines

Ground and phase faults within a DG facility should be cleared by protective devices within the facility that are set and coordinated to provide the optimum selectivity and speed. With radial distribution sourced from the utility—which is typical for a facility prior to the introduction of DG—coordination is typically performed from the source transformer with a three-phase fault and the ground fault is calculated using transformer impedance and assumed source impedance behind the source transformer (Figure 11).

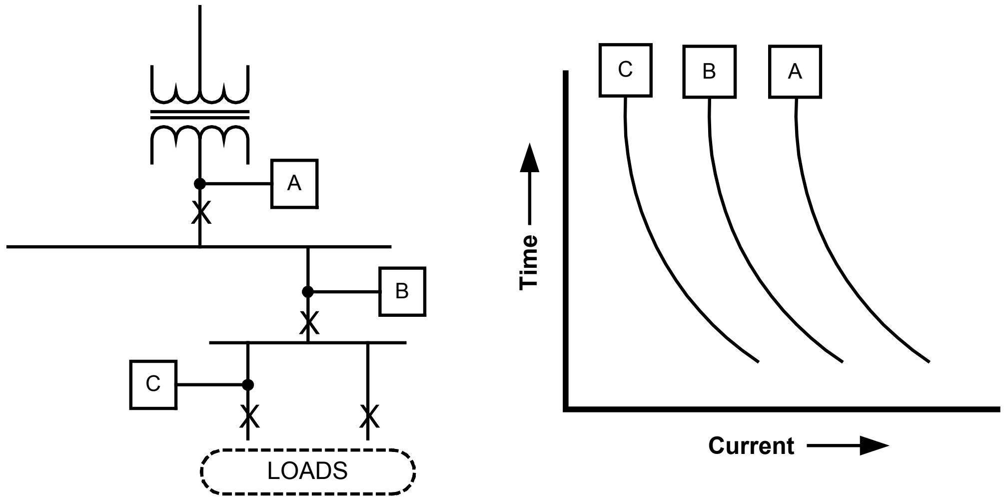


Figure 11 Radial Overcurrent Protection Coordination without DG

When DG is added (depending on the location of the DG interconnection protection CTs and VTs, and the setting and coordination applied), the DG may trip for faults that should be cleared by other facility devices. This may be especially true if the DG is connected to the bus that is fed from the point of common coupling (PCC) (Figure 12).

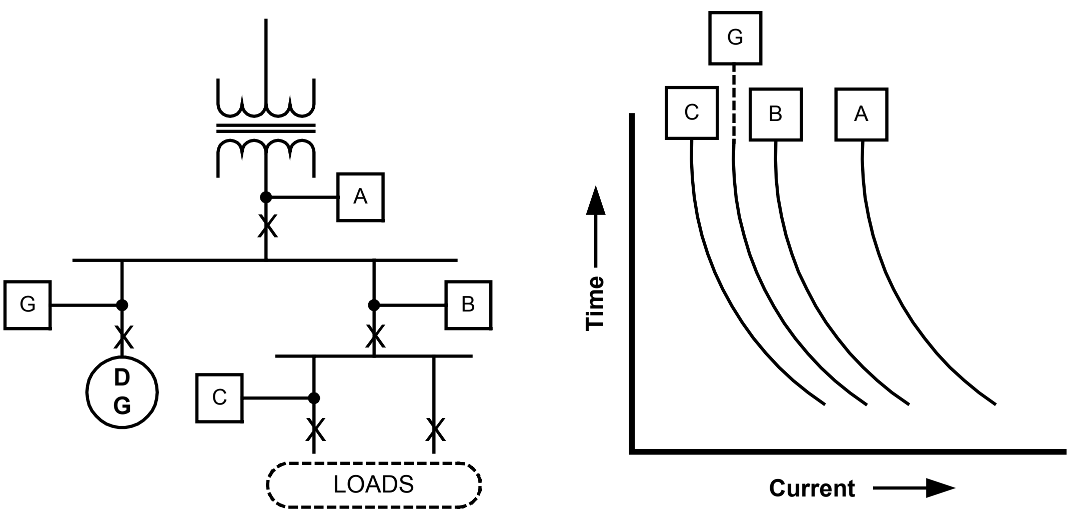
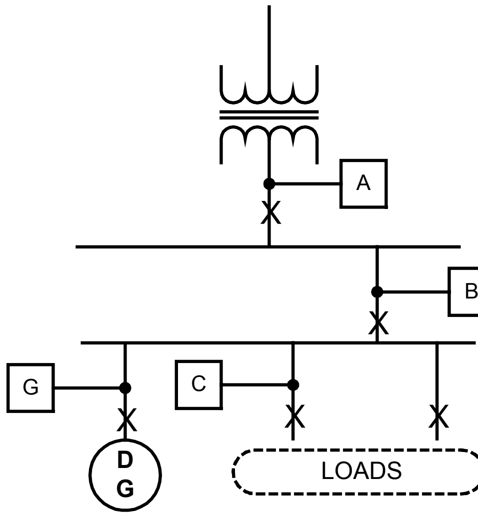


Figure 12 Miscoordination Example with DG

The coordination employed when the facility was operated from the radial utility source may no longer be secure due to the relatively long time that was allowed to clear nearby faults, as coordination to plant loads deeper in the facility had to be maintained. DGs located off of lower voltage buses are being coordinated with other protective devices at those levels, which typically trip faster than the protection near the point of common coupling as they are at, or near, the end of the radial distribution system (Figure 13).



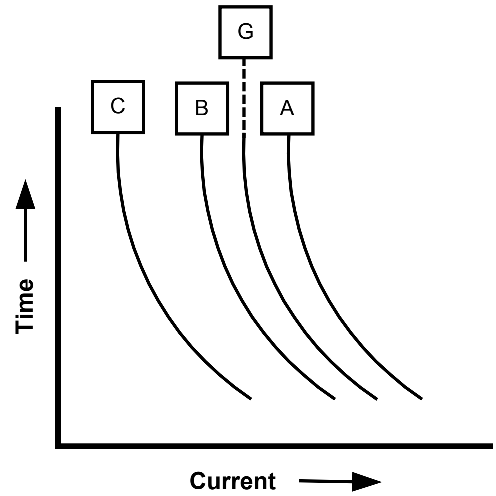


Figure 13 Coordination with DG at Remote Bus from PCC

Countermeasures to these possible miscoordination problems include:

1. Revise coordination of installed facility protection to speed up tripping if possible. This may be the least expensive option, as it may not require a protection device change-out, but rather a simple setting change. However, there are limits to the coordination time intervals (typically 0.3 seconds) that should be maintained, and therefore this option may not be possible (Figure 14).

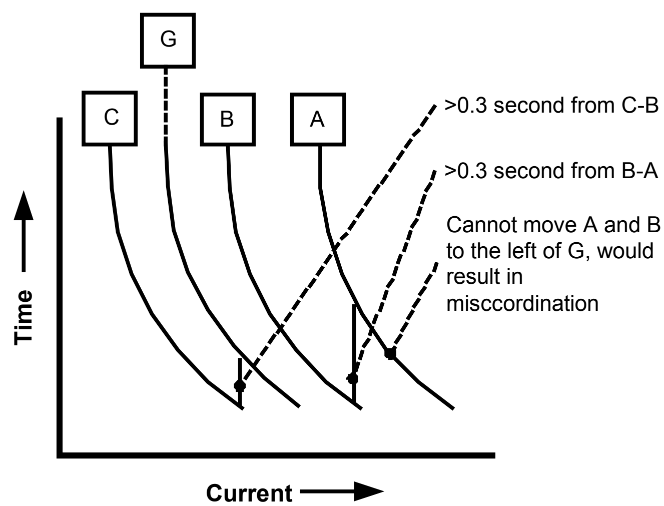


Figure 14 Coordination Problem to Speed Up Tripping with G to B & A

2. Directionalize the DG's overcurrent protection. This will permit high-speed tripping only if the fault is determined to be from the utility, versus within the facility. This strategy will

work if the DG protection is sourced from CTs and VTs at the point of common coupling as any fault in the utility's direction must be in the utility (Figure 15). If the DG has its CTs and VTs sourced from deeper within the DG facility, an overcurrent event that is determined to be toward the utility does not necessarily mean it is in the utility's system, but rather it may be in the DG facility's system closer to the point of common coupling (Figure 16).

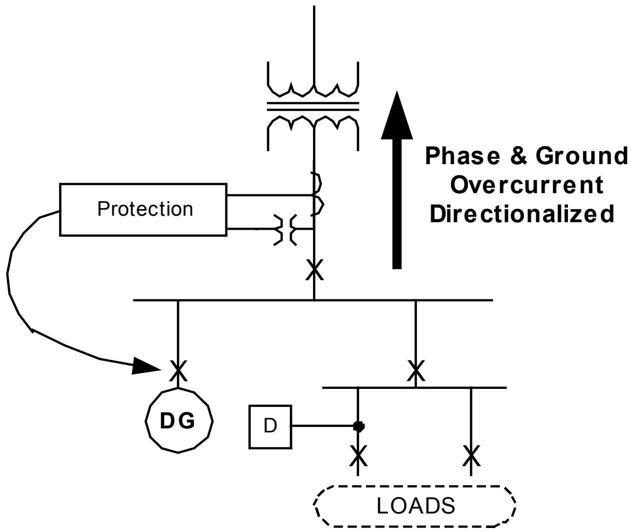


Figure 15 Employing Directional Elements at the PCC

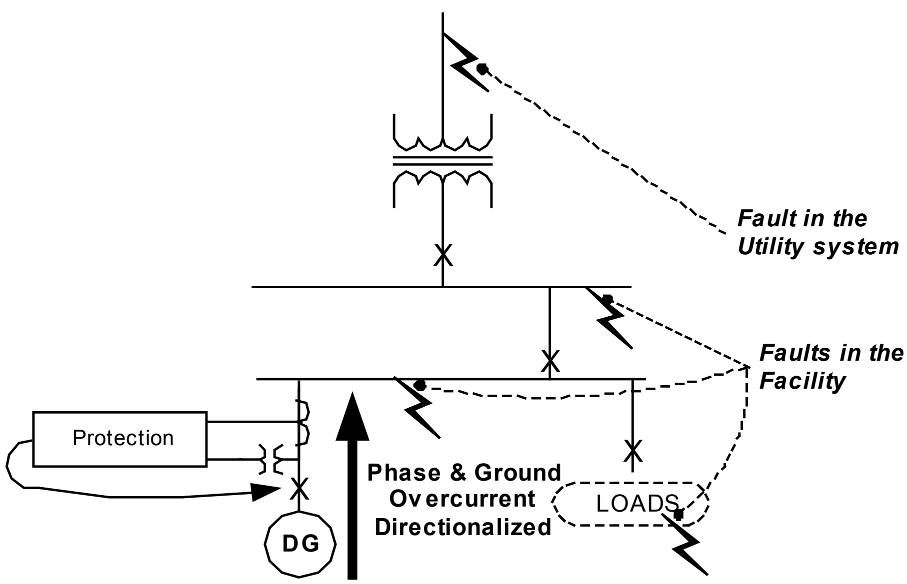


Figure 16 Employing Directional Elements with DG at Remote Bus from PCC

Conclusions

1. Utility DG interconnection guidelines are written in the utility's interest to assure rapid disconnection of DG from distribution systems for various reasons. The protection settings are typically derived for maximum reliability and speed, and not to maximize the security of the DG. Strict adherence to the interconnection guidelines does not necessarily guarantee secure protection for the DG facility.
2. The utility, project consultant, DG packager and facility owner/operator can all provide input to make a DG facility's interconnection protection more secure.
3. This paper has outlined two scenarios for consideration. Undoubtedly, more exist and will be "discovered" as DG continues to proliferate the distribution system.
4. It is hoped that this article has illuminated some considerations regarding DG interconnection protection security, and opens the door for continued learning and sharing of experiences to make DG interconnection protection more secure.

References:

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About the Author

Wayne Hartmann is Product Manager, Protection, and Marketing Manager for Beckwith Electric. He is responsible for application and marketing of Beckwith products and systems used in generator, transformer and DG interconnection protection, as well as synchronizing and bus transfer schemes.

Before joining Beckwith, he performed various assignments in applications engineering, project engineering and marketing with Siemens Power T&D, Alstom T&D, INCON, Siemens Energy & Automation, and Combustion Engineering. For more than 17 years in the industry, Wayne's focus has been on the application of protection and automation systems for power production, transmission, distribution and utilization.

Wayne is an active member of the Institute of Electrical and Electronic Engineers (IEEE) Power System Relay Committee, where he serves as a Main Committee Member, Vice Chair of the Rotating Machinery Subcommittee, and a contributing member of many Working Groups. He has authored and delivered numerous technical papers for the Georgia Tech Relay, Western Protective Relay, American Power, Western Power Delivery Automation, IEEE T&D and other conferences. Wayne has contributed to numerous IEEE Transactions, Tutorials, and Guides, and is a contributing author/editor for McGraw-Hill's *Standard Handbook of Power Plant Engineering, 2nd Edition*. He is a graduate of the State University of New York at Farmingdale, where he obtained an Associate in Applied Science Degree in 1980.